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NORTHERN FOREST EXPERIMENT STATION
FOREST SERVICE, U. S. DEPT. OF AGRICULTURE
JUNEAU, ALASKA

foreword

Our Forestry Sciences Laboratory on the campus of the University of Alaska was dedicated in July. This new facility contains office and laboratory space for our scientists and supporting staff concerned with the research program for the Interior forests.

Also, the Bonanza Creek Experimental Forest was formally established. This 8,300-acre tract was made available to us on a long-term lease by the State of Alaska through the Department of Natural Resources. The Experimental Forest contains an excellent stand of white spruce and limited stands of aspen and paper birch. Its accessibility, about 25 miles from College on the Nenana Road, is another favorable feature.

Laboratories and experimental forests provide us with opportunities to gain a better understanding of Alaska's forest resources. Such knowledge, in turn, will prove useful to those administering, utilizing, and owning forest resources.

Richard M. Hurd

Director

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Northern Forest Experiment Station

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insects

An analysis of the insect situation in the Coastal forests of Alaska was completed during 1963. This analysis pointed up that first priority for research should be given to two associated defoliating pests -- the black-headed budworm and the hemlock sawfly. The ultimate goal of the research is to find ways to minimize the damage caused by these pests. This will require keeping their populations at low levels using various control measures. Before such measures can be used effectively and safely, detailed information about these insect pests is needed. For example, the effects of weather, disease, parasites, and predators must be evaluated for each insect. Data are also needed on life stages, feeding habits, and reproductive ability. To gain some of this information we established a field camp and study area 20 water miles from Juneau (fig. 1).

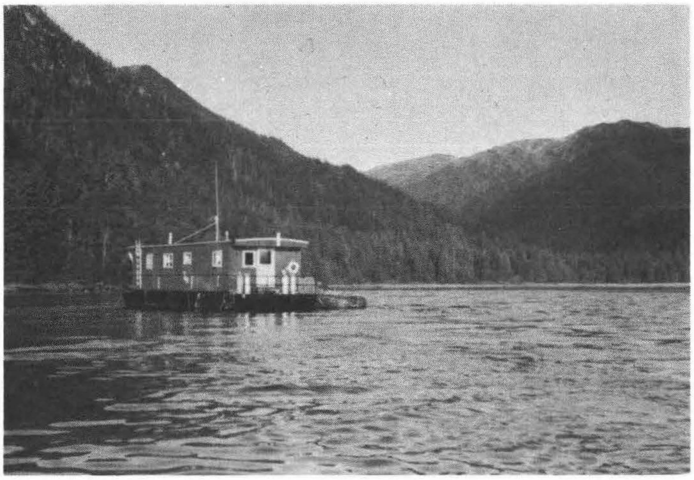


Figure 1.—Wanigan 14 served as the floating base for the insect research in Limestone Inlet, 20 miles from Juneau.

Number of budworm eggs found on the lower tree crowns during the fall is generally used to forecast next year's insect population and, thereby, estimate possible damage to the forest. During the overwintering period there undoubtedly is some egg mortality, but the magnitude is not known. To get this information we periodically examined specific egg-bearing leaves during the winter and spring (fig. 2). We found 26 percent of the eggs were destroyed or failed to hatch.

Does the same mortality percentage apply to upper crowns of the trees, which are generally the preferred egg-laying areas? Steel towers are now being used to provide access to aid in answering this question and to study insect development in the tops and middle crowns of the trees (fig. 3). As a result, we will be able to compare the mortality from different levels of the tree crowns. If mortality determined from the ground is a good index of total mortality, then the observations can be made much more cheaply and efficiently.

Figure 2.—Don Schmiege and Bob Paulus checking the survival of budworm eggs.

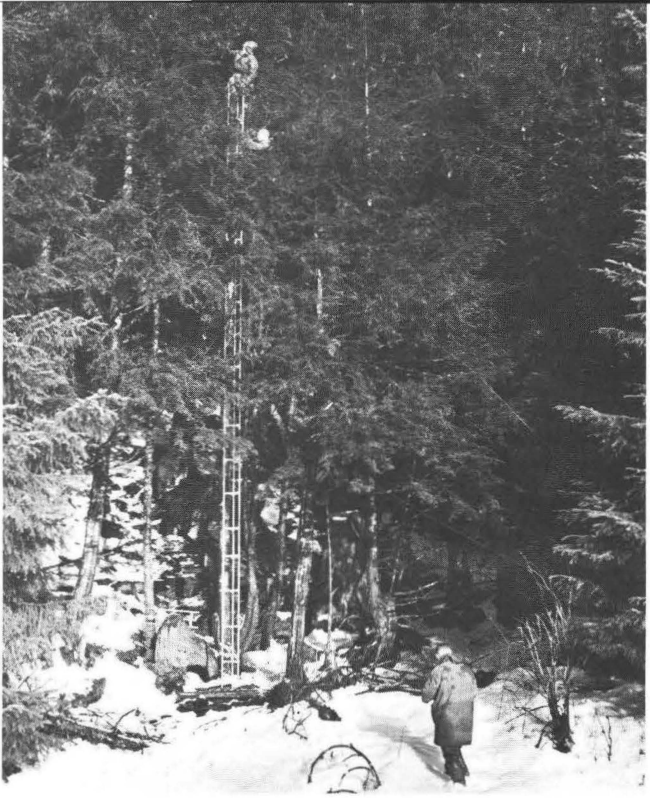


Figure 3.—Forty-foot steel towers are used to determine budworm egg mortality in the middle and upper tree crowns.

Reproductive potentials of an insect contribute directly to the theoretical insect population. An insect laying 100 eggs compared to one laying 200 eggs is not as serious a threat if all other factors such as feeding habits of the larvae, susceptibility to insect parasites and predators, and other natural controls are the same.

The average number of eggs laid by a female budworm is not known. During the past field season, we set up rearing cages in our field laboratory. The budworm in these rearing cages produced an average of 86 eggs per female of which only 63 eggs were laid. The remaining 23 eggs were retained by the female. The larvae in the laboratory rearing cages developed into smaller pupae and smaller adult females than those found in the natural environment. The laboratory-reared females produced and laid about one-third fewer eggs.

The hemlock sawfly, a companion defoliator of the Coastal forests, over-winters in two forms--egg and prepupa. The female lays from 30 to 100 eggs, which are inserted into the edges of hemlock needles where they remain over winter. These hatch the following spring when they go through the larval and pupal stages to emerge as adults. After mating, this cycle is repeated. In that stage where the larvae spin cocoons and over-winter as prepupae, we suspect pupation is completed the following spring when the insect emerges as an adult.

The significance of this two-stage over-wintering behavior is not known. However, the behavior pattern could influence control measures. If parasites and predators are used to control the hemlock sawfly, the life cycle of the parasite must be synchronized with that of the host--the hemlock sawfly.

What controls the over-wintering behavior of the hemlock sawfly?

Muslin sleeve cages were placed around hemlock branches containing overwintering prepupae to see if this is a genetic relationship (fig. 4). The adults that emerge will mate and eggs will be laid in the hemlock needles within the sleeve cage. If the larvae from these eggs over-winter as prepupae, there will be strong evidence of a genetic relationship.

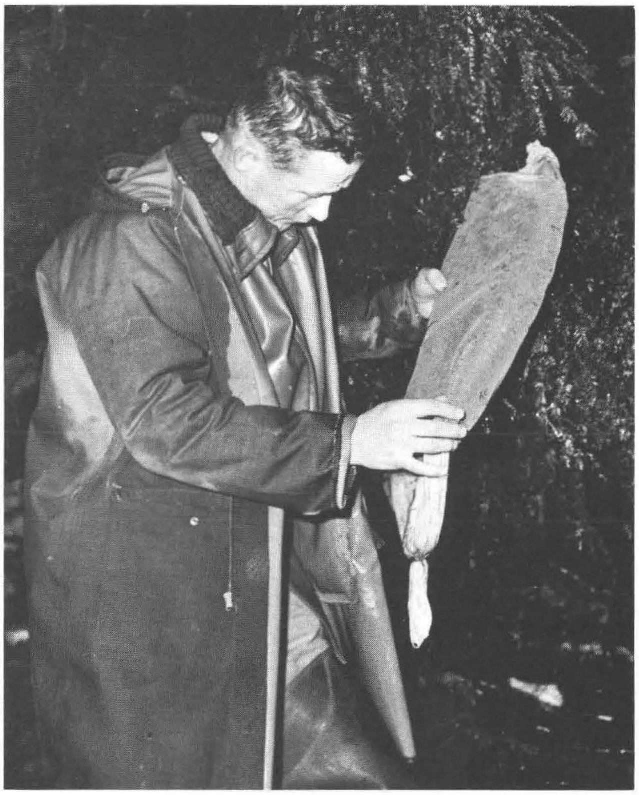


Figure 4.—A muslin sleeve cage containing a branch with overwintering prepupae of the hemlock sawfly is examined by Don Schmiege.

forest survey

Our activities this year were concerned primarily with completing the office-related phases of the inventory for the interior Alaska forests. Because we used aerial photographs extensively in this inventory, a great deal of photographic interpretation was required. Skillful use of photographs enabled us to classify land either as forest or non-forest, and further segregate forest stands by tree species and volume per acre. These data are then processed by electronic computers to obtain summary tabulations. At the end of the calendar year, data were still being compiled and readied for the computer.

Plans were made for future inventories in both the Coastal and Interior forests. Procedures for sampling the Coastal forests were devised and tested in the Juneau area. New practices will be used on the reinventory. They will be more efficient both in kind and amount of data collected and the time spent in collecting data. Collecting data on the ground is time consuming and costly. The greatest cost both in research time and cash outlay can be in traveling to and from widely distributed sampling points. Because of high travel costs we wish to use those procedures that will yield the maximum amount of information from any one sampling point. We were using the nearby Juneau area to test the efficiency of future operations.

Forest survey activities include more than a physical inventory of timber volume on the ground at a given time. For example, we want to determine how fast the volume is increasing through growth and, conversely, how fast the volume is being decreased by man's use and by diseases, insects, and fires. To get at least a rough measure of the possible decrease caused by fire in the Interior forest we started a study with the active aid and cooperation of the Bureau of Land Management. Our plan involves sampling a number of recent burns and evaluating probable loss at the time of the fire as well as loss in future growth and volume. This study is slated for completion next year.

Another phase of our forest survey activities is to determine how well our estimates of merchantable timber volumes correlate with the volumes actually used in a logging operation. We sampled 21 logging operations in southeast Alaska to get our answer. As an over-all average we found that, for every 1,000 board feet we classified as merchantable, 921 board feet were removed. Thus, the material or residue left in the woods is the equivalent of 79 board feet. This residue could be conveniently grouped into three categories: broken chunks and cut sections missed or left--23 percent; merchantable volume left in tops and stumps--38 percent; and trees classed as merchantable but not cut--39 percent (fig. 5).

Most of the operators recovered from 70 to 80 percent of the volume scaled as merchantable. Those recovering over 80 percent usually cut lower stumps and cut to a smaller top diameter than used in our inventory. Operators recovering less than 70 percent of the scaled volume either experienced excessive breakage in falling, failed to cut logs with required trim allowance, cut logs too long, cut stumps too high, or left merchantable volume in the tops.

We found that small operators tend to leave few logs in the woods. On two-man operations, one man falls and bucks while the other yards with a tractor. Few logs are missed in yarding on these operations. Residue usually was in small diameter trees not felled.

Large operators use a number of fallers working in advance and independently of the yarding crew. They fall and buck trees according to instructions given them and without particular interest in yarding problems. In the jumble of logs, limbs, and tops that usually results, choker setters often miss logs and break logs in the yarding operation (fig. 6). Missed and broken logs were found in drainages. and depressions at right angles to the direction of yarding, at the toe of slopes where yarding was downhill, and at the landing.

Figure 5.—Small but merchantable trees were sometimes left uncut.

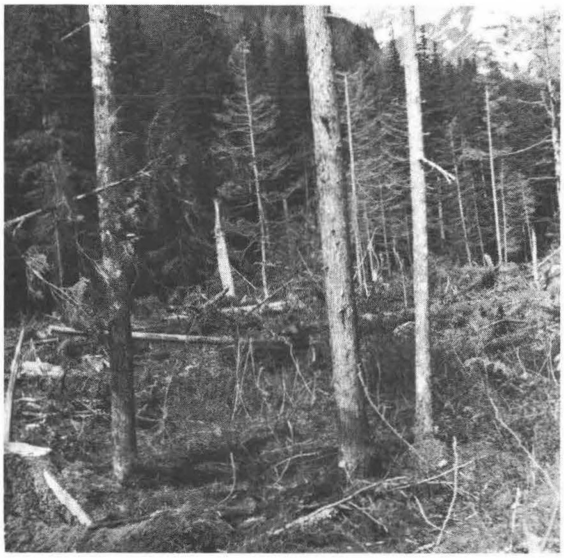
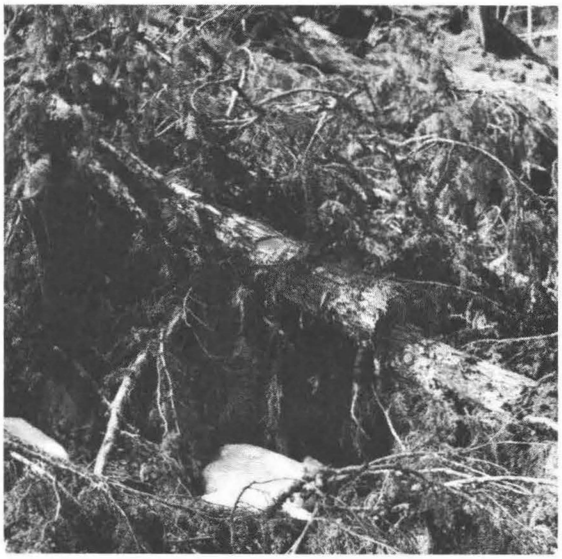


Figure 6.—A merchantable log left on a sample plot.

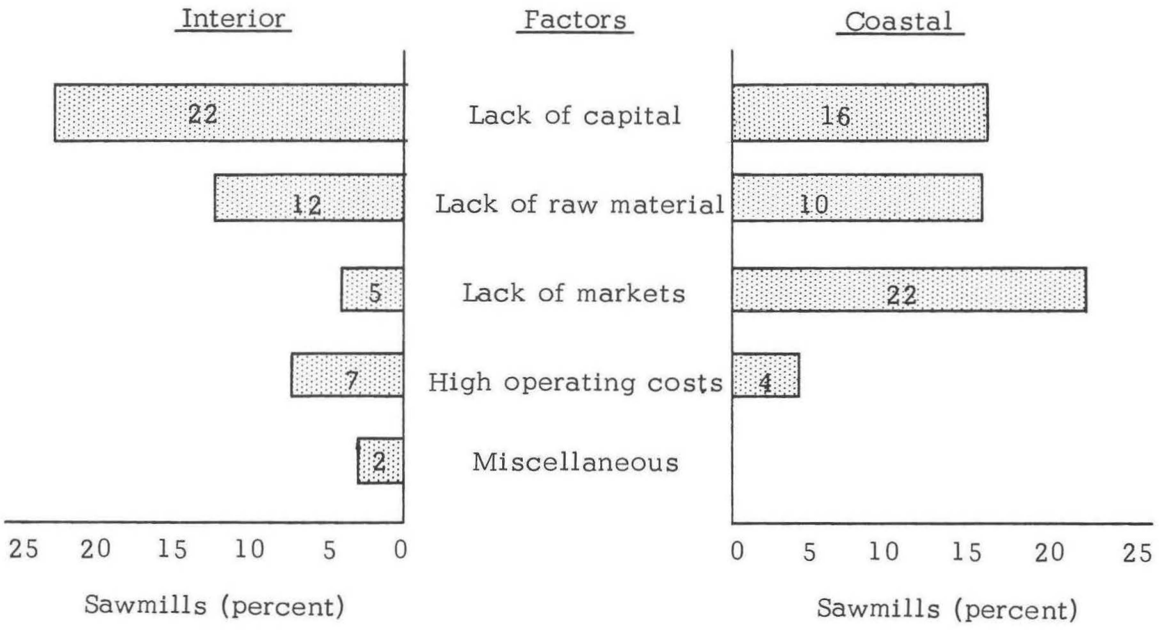


As would be expected, defect in trees increased with tree size. Large trees usually were bucked to eliminate defective sections unless tree-length yarding and hauling was taking place. Long butting was a common practice of all operators.

The results of a statewide canvass of all wood products manufacturers were published in our Resource Bulletin, "Wood Processing in Alaska--1961." This canvass showed that, in 1961, over 99 percent of the 339 million board feet of logs consumed came from coastal Alaska trees. Seventy-nine percent of the total volume of logs consumed was processed into pulp by Alaska's two pulpmills. Only 7 percent of the lumber produced by Alaska mills was sold within the State, although consumption of lumber and wood products in Alaska far exceeded the total production of Alaska sawmills.

During this statewide canvass, sawmill owners were asked what major factor limited their plant expansion. Lack of capital seemed to be the greatest statewide deterrent to plant improvement and expansion (fig. 7). Coastal mill owners, however, responded most frequently that lack of markets was their greatest problem. Although these mills have an unlimited market for the high-grade material (clear factory and select-shop cants) in the Pacific Northwest, total production is limited by their inability to furnish the common grades of lumber at a competitive price.

Figure 7.—Factors limiting expansion of sawmills in the Interior and Coastal forest regions, 1961.

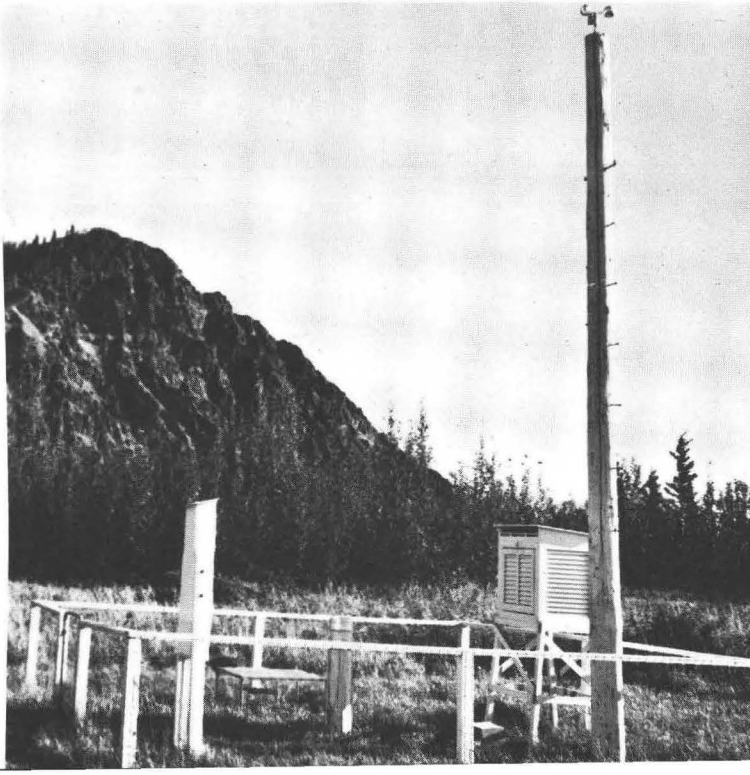


fire

The analysis prepared this year to guide our forest fire research program recognized two broad problems--fire behavior and fire control systems. The behavior of fire is considered basic to the effectiveness of all systems for controlling fire. Consequently, it is our intent to gain a better understanding of fire weather, types and characteristics of Alaskan fuels, factors useful in predicting fire hazard, and the actual behavior of free burning fires in various kinds of fuels. The broad problem of fire control systems has been subdivided into detection, suppression techniques, planning methods for control, and fire prevention measures. Our research on these two broad problems will be concentrated on those phases promising to yield immediate benefits to those having responsibility for protecting forest and related resources from fire.

Weather has a major influence on the start, spread, and control of interior Alaska forest fires. Consequently, we started a study of specific weather elements, including temperature, relative humidity, wind, and precipitation to determine how they relate to fire activity. These elements will be observed and recorded daily throughout the fire season at a network of 18 stations maintained and operated by the Bureau of Land Management and the Forest Service (figs. 8 and 9). This network will be expanded to include some existing Weather Bureau stations. Additional stations will be added to the network to provide more complete fire weather information for the 220 million acres where fires are known to occur.

Figure 8.—Fire weather station near Eagle. Wind velocity is measured at a 20-foot height to reduce any disturbance caused from nearby obstruction.



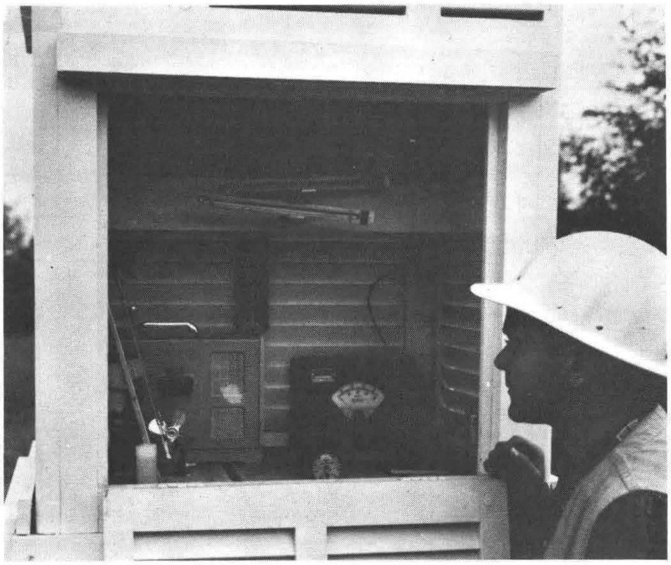


Figure 9.—The louvered shelter provides a uniform exposure for instruments used to measure and record temperature and relative humidity.

High ambient temperatures and low relative humidity favor the spread of wildfires. The long hours of daylight associated with summers in the northern latitudes can produce both high temperatures and low humidities. Furthermore, the long daylight hours during the fire season tend to reduce the magnitude of the characteristic diurnal change of temperature and humidity (fig. 10). Also, there is a low hourly change of these weather elements for the average 24-hour period. Because of this reduced diurnal fluctuation of temperature and humidity we can normally expect long periods favoring the rapid rate of spread for interior Alaska fires.

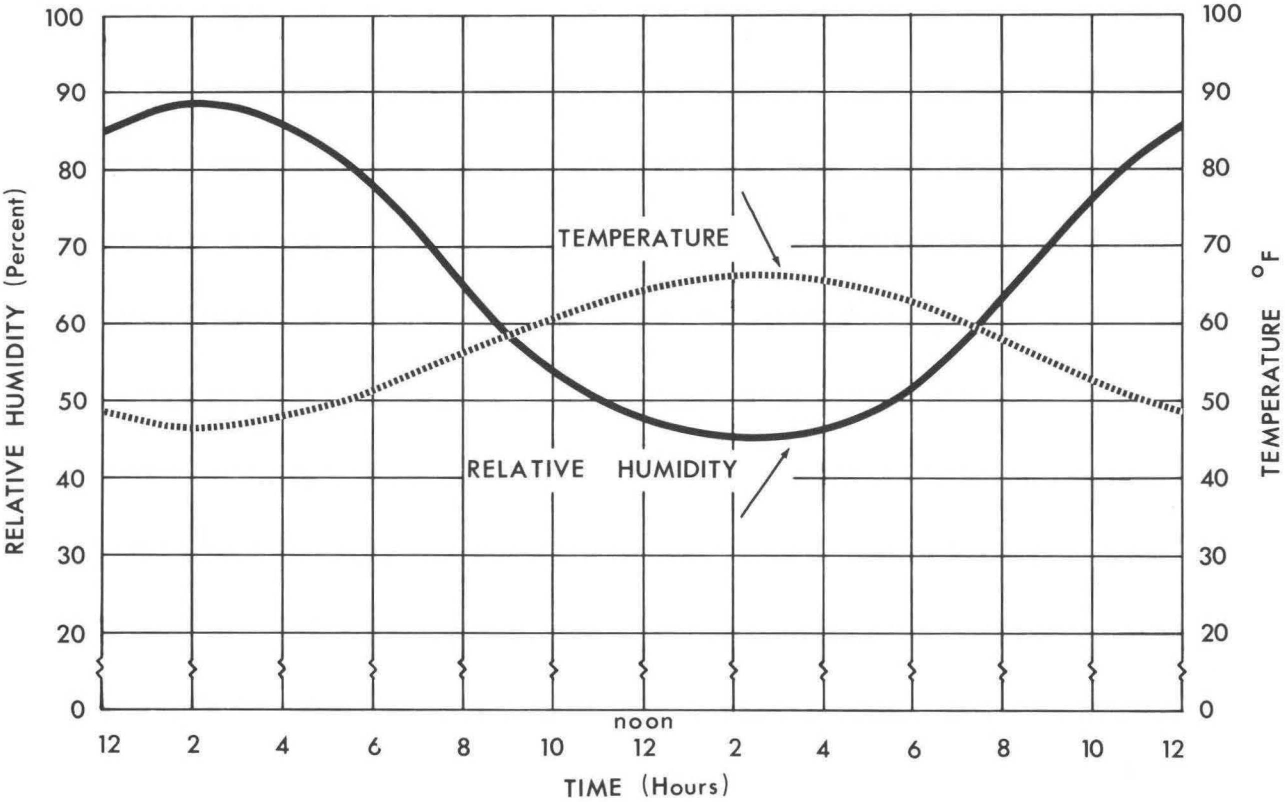


Figure 10.—Preliminary analysis of seasonal fire weather data for Fairbanks showing the average daily maximum temperature and minimum relative humidity.

trees

interior forests

In 1958, when we began our program of silvicultural research in interior Alaska, the most immediate need was information on the potential of commercial forest lands. What could they produce? Until this year we were concerned chiefly with collecting and analyzing data, and developing working tools that would help answer this important question. Now, much of this work is nearing completion. Our program, in 1963, began shifting to studies of a more fundamental nature relating to establishment and growth of Interior tree species.

We completed preparation of 16 equations and tables for estimating total and merchantable cubic-foot tree volumes. Their construction involved precise volume measurement of about 1,400 aspen, paper birch, poplar, and white spruce sample trees throughout the Interior. The equations for estimating volumes were developed by analyzing the several measured predictor variables (tree diameter, height, form, and combinations of these) with electronic computer facilities available at the University of Alaska.

Field work for preparation of aspen and paper birch growth and yield tables were also completed this year. Eighty aspen and 108 birch plots have been established and sampled. Data analysis is under way. The tables will allow us to evaluate forest land potential in terms of values such as wood volume and number of trees per acre by productivity and stand age classes. They will show land managers and others interested in evaluating the forest resource what the land can produce, how long it takes to produce it, and the effect of site upon productivity.

Both aspen and birch stands have shown a remarkably uniform pattern of origin and development. They usually invaded upland sites immediately after fire. Stands of these pioneer hardwoods are, therefore, usually even-aged and well stocked. Both species are comparatively short lived; stands begin to deteriorate between 60 and 100 years of age due to rot and injury caused by disease pathogens and insects. The stands that we sampled ranged from 25 to 125 years old (figs. 11 and 12).

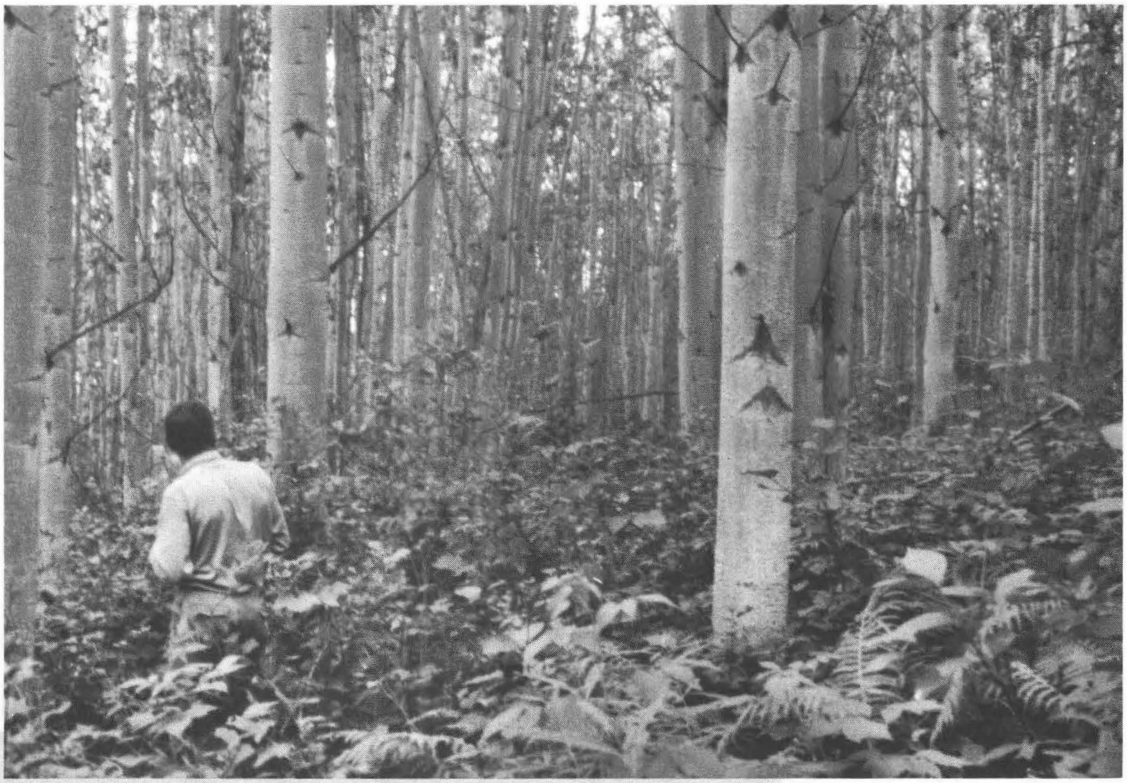


Figure 11.—These 45-year-old aspen are growing on one of the many sample plots. Although individual trees are small (they seldom exceed 13 inches in diameter and 80 feet in height) there are many stems per acre and the stands are often extensive.

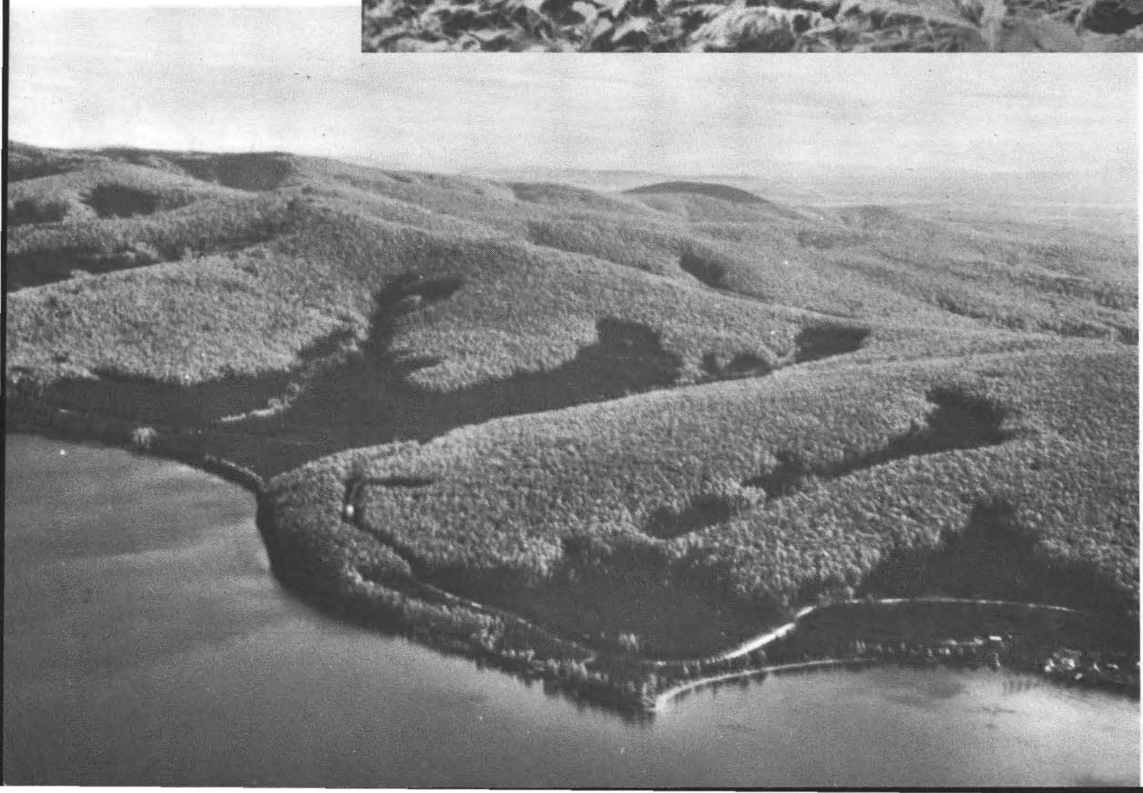


Figure 12.—A 103-year-old birch stand of about average yield for the Interior. Only 3 or 4 percent of the trees are 11 inches and larger in diameter so there would be very little sawtimber volume. But throughout the extensive area occupied by this stand there are almost 400 trees per acre, averaging about 7 inches in diameter and having a gross merchantable volume of 2,500 cubic feet—a respectable yield in terms of pulp or fiber production.

Growth and yield of white spruce is our remaining study relating to land productivity. Preliminary work, to develop techniques for constructing white spruce growth and yield tables, was conducted this year. White spruce was reserved until last to benefit from experience gained in preparation of the other tables.

Many of the best commercial stands of white spruce in Alaska are located on the flood terraces of the Tanana and Yukon Rivers and their tributaries (fig. 13). As utilization of Interior forests develops these lands will be of extreme importance for they have a high productive potential, considerable continuous area, level topography for ease in logging, and natural avenues -- the rivers -- for timber extraction.

In 1963 a study was begun to provide needed information on the ecology of river-bottom white spruce stands. Some of the questions that the study hopes to answer are: How have these white spruce stands originated and how long did it take them to develop? What represents maturity in the white spruce stands? What is the pattern for forest succession after maturity? What are the effects of fire in the river-bottom sites? What is the role of permafrost in plant succession along the rivers? What are the effects of periodic flooding by the rivers?

Although the work in 1963 was of a preliminary nature it became apparent that the relationships between the vegetation and permafrost are especially important in river-bottom sites and will warrant considerable investigation as the study progresses. As the white spruce stands develop, a thick layer of moss grows on the forest floor. This acts as an insulating mat in summer and the soil retains the cold from the long winter. Cold soils or permafrost may develop and white spruce growth becomes slow. If the condition persists, the white spruce may be replaced by the permafrost-tolerant, but more slow growing, black spruce. If flooding occurs frequently enough, however, the moss mat is destroyed by the deposition of river silt, the soil remains warmer, and the white spruce continue to grow, sometimes reaching an age of 300 years. Thus, periodic flooding along the rivers of the Interior may be an important reason for the growth and development of valuable white spruce stands in an area that more commonly produces the less desirable black spruce. As the

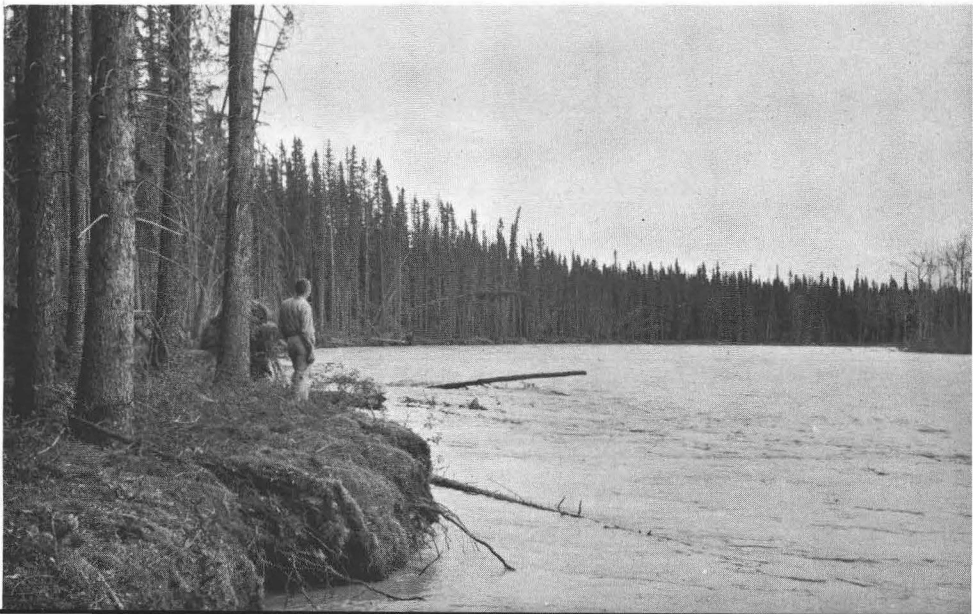


Figure 13.—This 140-year-old white spruce stand along the Tanana River illustrates the potential of the "river-bottom sites."

study continues we hope to obtain more definite information on the relationship of permafrost and flooding to the white spruce stands. Our ultimate aim, of course, is to develop management practices that will aid in fully utilizing the inherent productivity of these important sites.

Forest tree seeds are eaten by small mammals such as squirrels and mice, insects, and damaged by disease. It is important to know the extent of these losses, for only then can we determine if enough naturally produced seed will be available for regeneration. Two studies dealing with white spruce seed loss were concluded this year.

In a cooperative study with the Department of Wildlife Management, University of Alaska, feeding habits and population density of squirrels were investigated. Feeding trials were performed with captive squirrels held in cages (fig. 14). Flying squirrels lost weight rapidly and could not survive on a diet of white spruce seed alone. Flying squirrels seemed to prefer most other foods to spruce seed, making it seem unlikely they consume much spruce seed in the wild. Red squirrels, however, displayed a preference for white spruce seed and survived very well on it alone for periods up to three weeks. When both black and white spruce seed were made available to red squirrels they displayed a marked preference for white, and when put on a diet of black spruce only they lost weight rapidly. White spruce seed was found to have a higher caloric value.

A daily average of 144 white spruce cones supplied the seed eaten by each captive red squirrel. In the wild, supplementary foods undoubtedly reduce this figure, but it is certain these animals eat significant amounts of seed and may eat most of the available seed, especially in years of poor cone crops. Observations indicate the red squirrel population varies from two to eight per acre in white spruce stands of interior Alaska. It appears that red squirrels compete for white spruce habitat with the less successful squirrels being forced into black spruce stands.

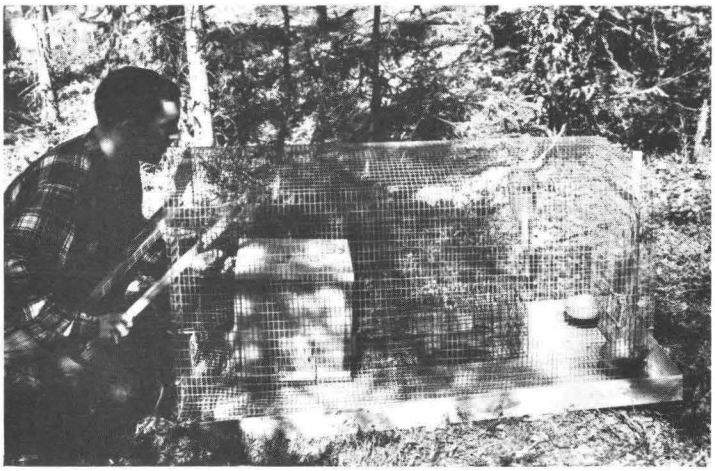


Figure 14.—A series of gages located in a fenced area with a black spruce stand were used in determining the amount of black and white spruce seeds and cones used by red and flying squirrels.

In a cooperative study with the Forest Insect project of our Station, insect damage to white spruce cones and seed was observed for five successive years. During this period insects damaged from 3 to 6 percent of the seeds in the sample cones collected in four of the five years. In one year (1962) damage increased to 50 percent. Both cone and seed damage was least when there was an abundant cone crop and the number of seeds per cone was high. In contrast, the greatest insect damage was caused when few cones were produced but the number of seeds in each cone was high. Insect damage to cones varied from 15 to 89 percent during the 5-year period.

coastal forests

Analyzing the data from the "regeneration" studies and preparing the results for publication took much of our time. These studies started ten years ago when large-scale, clear-cut methods of harvesting old-growth stands for pulpwood began in Alaska. At that time, there was concern whether natural regeneration could be relied upon to promptly reforest extensive clear-cut areas. The factors we followed that bore directly on the establishment of the new forest on large cuttings included amount and periodicity of seed production by stands adjacent to the logged areas; the distance seed was carried by wind into the clear cuttings; the effect clear cutting had on the populations of small, seed-eating mammals; the kind of seedbed conditions that were conducive to seedling establishment; and the species composition of the new forest. Generally, satisfactory seedling stands have become established on these large cuttings. Complete results of the studies will appear in forthcoming publications.

Also, during the year we examined 30 relatively small areas that had been clear cut 10 to 45 years ago. We were after additional information on the establishment and growth of young, even-aged stands (often called second-growth stands). The examination of these areas, generally on favorable sites, supports the belief that natural regeneration can be relied upon for the relatively rapid establishment of new stands (figs. 15 and 16).

Figure 15.—A stand of high quality Sitka spruce and western hemlock was harvested on this Long Island site in 1941.

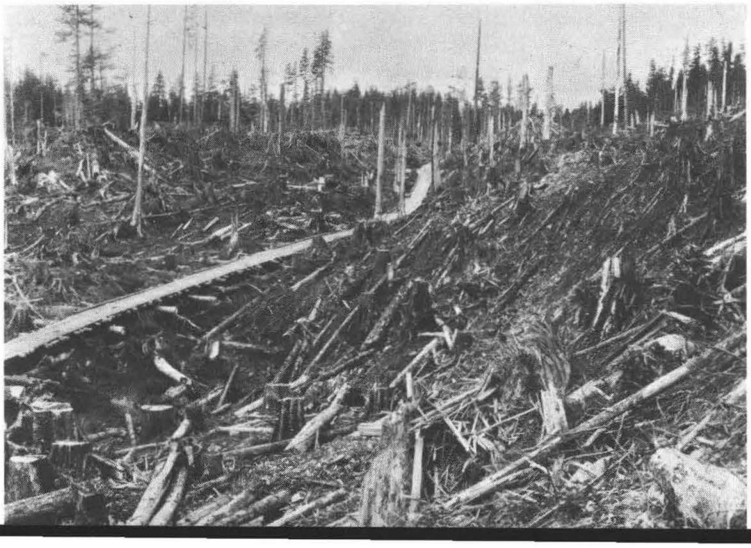
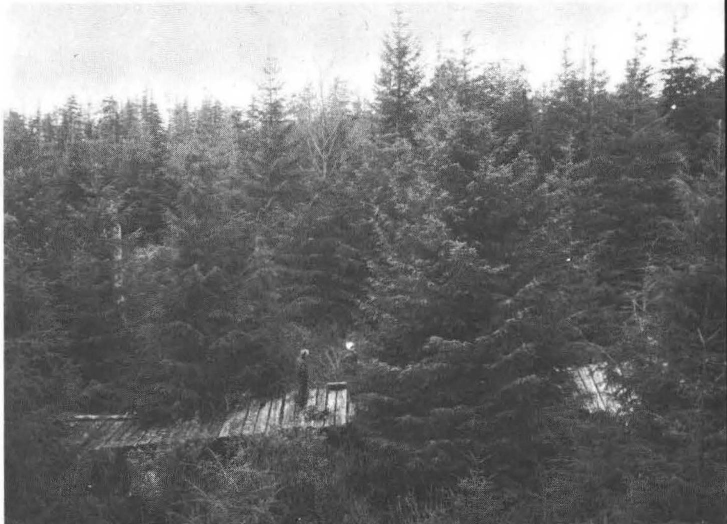


Figure 16.—Today, 22 years later, the Long Island site has a vigorous stand of Sitka spruce and western hemlock that originated from natural seedfall.



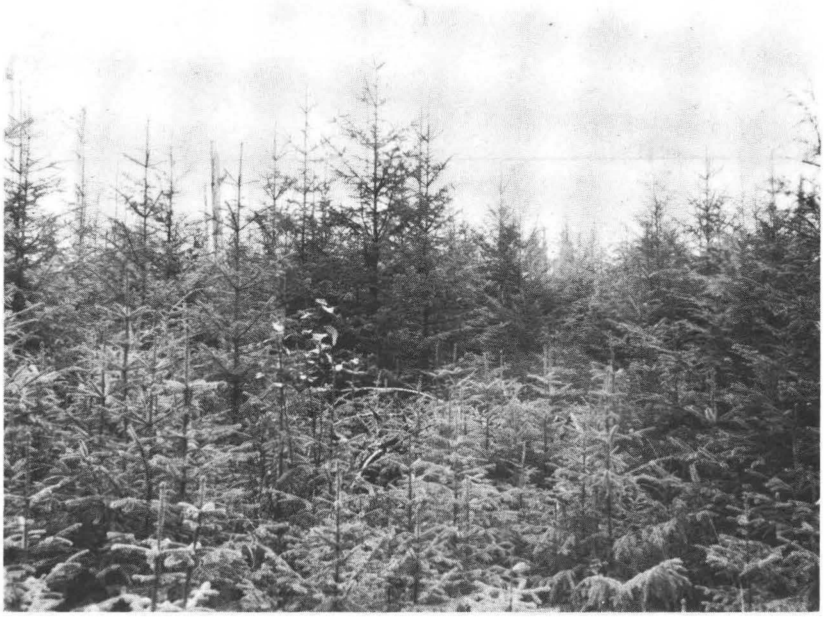


Figure 17.—A 16-year-old stand on Kupreanof Island is too dense for maximum growth of the better trees.

In many cases, conditions that favor seedling establishment lead to over-dense stands (fig. 17). Stagnation was not apparent in any of the dense stands examined, but competition was often severe and growth restricted. Many stands contained great numbers of suppressed dead and dying trees (fig. 18).

Vigorous growth and well-stocked stands suggest that, when ready for harvest (110 years old), even-aged unmanaged stands may contain twice the wood volume of the old-growth uneven-aged stands they replaced. The potential growth of managed even-aged stands on high quality sites is yet only speculation.

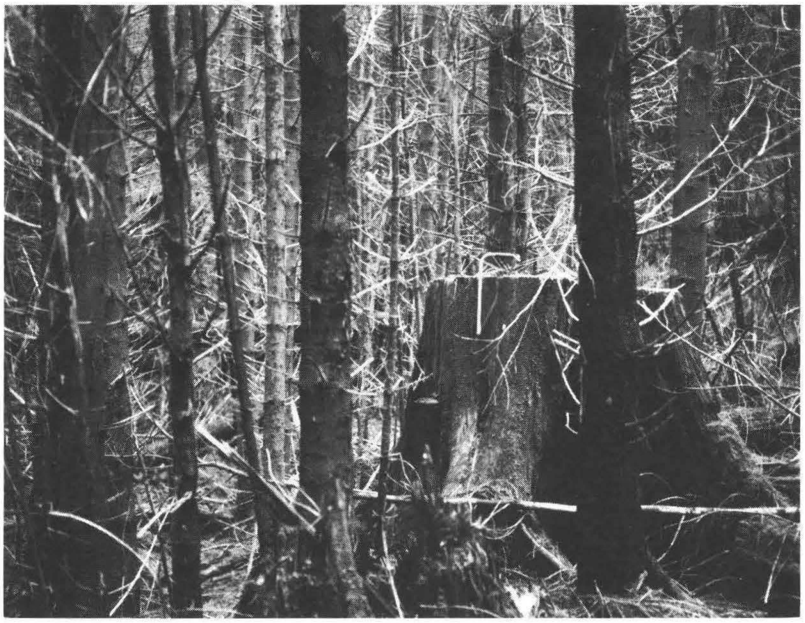


Figure 18.—Thirty-nine years after logging, dominant trees in a Dall Island stand are 80 feet tall and 10 inches in diameters. The many small, suppressed trees that are dead or dying indicate early dense stocking.

soil and water

Progress in soil and water research included analyses of results on:

Landslides on logged areas,

Effects of logs and debris in limiting salmon-producing streambed area,

Effects of log debris jams on streambeds,

Sedimentation in a salmon stream.

Landslides on logged areas received a major amount of our time. The result was a manuscript to be published in the Station's Research Paper series in 1964. We are summarizing our landslide work in this Annual Report.

Southeast Alaska is a land of long, deep, and spectacular fjords. Such a bird's-eye view shows the classical U-form of glaciated valleys; a topography carved by ice as the glaciers moved toward the sea. Along the north or northeast margins of the region, there are many glacial remnants of the last ice age. Southeast Alaska is a scene of change; a land in its dynamic formative stage. As the ice disappears, the land--and the landscape--seek a new stable form. This, in a large measure, is the land being logged in southeast Alaska -- often steep and sometimes of doubtful stability.

Nearly 70 landslides and debris flows occurred on steep logged slopes in the Maybeso Creek valley, about 40 miles west of Ketchikan, Alaska, during heavy October rains of 1961. Slides also occurred on clear-cut slopes of other logged areas hit by these rains. Did logging stimulate or trigger these soil mass movements? If logging affected landslide occurrence, how did it do so? A few slides were in, or started in, uncut timber. To suggest answers to these questions, a reconnaissance study was begun in 1962.

Recurring aerial photographic coverage provided a way to determine previous as well as recent landslide occurrence in the Maybeso Creek valley (table 1) on Prince of Wales Island. The first slides recorded, after logging began in 1953, occurred during 1952-59. Between the 1959 and 1961 aerial photography, new slides were observed as well as an increase in size of ones that occurred in the 1952-1959 period. The area in slides increased three and one-half fold between 1959 and 1961. In 1961-62 the change was drastic. These are the slides that occurred in October 1961. The increase from the previous photo record is four and one-half fold.

Table 1.--Acreage and number of slides by periods between aerial photography in the Maybeso Creek valley drainage

When photos were taken	Time period	Area affected		Number of slides		
		For time period	Cumulative total	On uniform slope 1/	In concentrated drainages 2/	Total for time period
	years	acres	acres			
BEFORE LOGGING						
June 1948	100	27.3	--	2	10	12
July 1952	4	4.2	31.5	0	1	1
DURING AND AFTER LOGGING 3/						
May 1959	7	6.2	37.7	2	18	20
May 1961	2	21.6	59.3	2	26	28
August 1962	1	90.8	150.1	16	52	68

1/ These slides occurred on the smooth, flat slopes between major side drainageways.

2/ These slides occurred within concentrated (V-shaped) drainages.

3/ Logging began in 1953.

Rainfall is one of the most apparent triggering forces causing slides in southeast Alaska. However, it is also clear that the rains which accompanied the record number of slides in 1961 might be expected at least once in a decade. Slides have not occurred on the unlogged slopes of Maybeso Creek valley at that great a frequency.

The reconnaissance study of landslides showed that:

1. Flows are more frequent within the V-notch side-drainages (fig. 19) than on the smoother glacial valley walls. This may be attributed to V-notch channel downcutting and producing oversteepened slopes.

2. Flows or avalanches usually slide on relatively smooth, wet planes oriented parallel to the slope when this plane is composed of such materials as glacial till, iron-organic layered material, metamorphosed sediments, or diorite (fig. 20). Such planes are resistant to downward water passage; hence, moisture builds up immediately above this layer.

3. Limited evidence leads to the assumption that southeast Alaskan flow-prone soils are usually cohesionless. These soils tend toward a single-grain structure with little interparticle bond. An extreme example of cohesionless soil is dry sand. Southeast Alaskan flow-prone soils lack the more complex shear strength properties of cohesive clay soils. Shear strength is an important factor in the behavior of soil under loading. For example, the stability of soil on slopes depends directly on shear strength or resistance to applied forces that cause or tend to cause contiguous parts of the earth mantle to slide relative to each other.

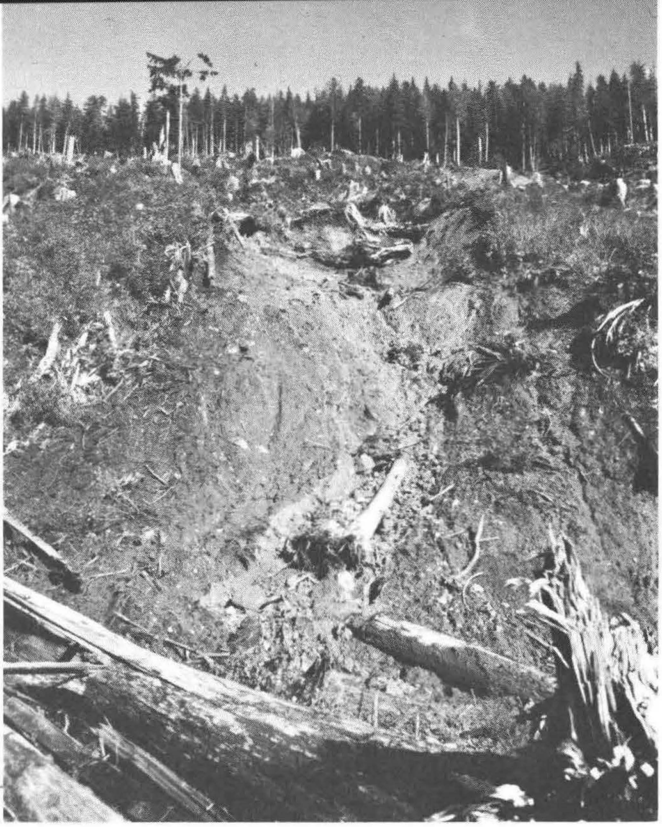


Figure 20.—A debris avalanche-flow moved on compacted glacial till, the lighter tone in the flow area.

4. A greater addition of water weight to the soil mantle through rainfall is not a likely stimulus for increased flows after logging. Research in other areas indicates that water infiltration rate into

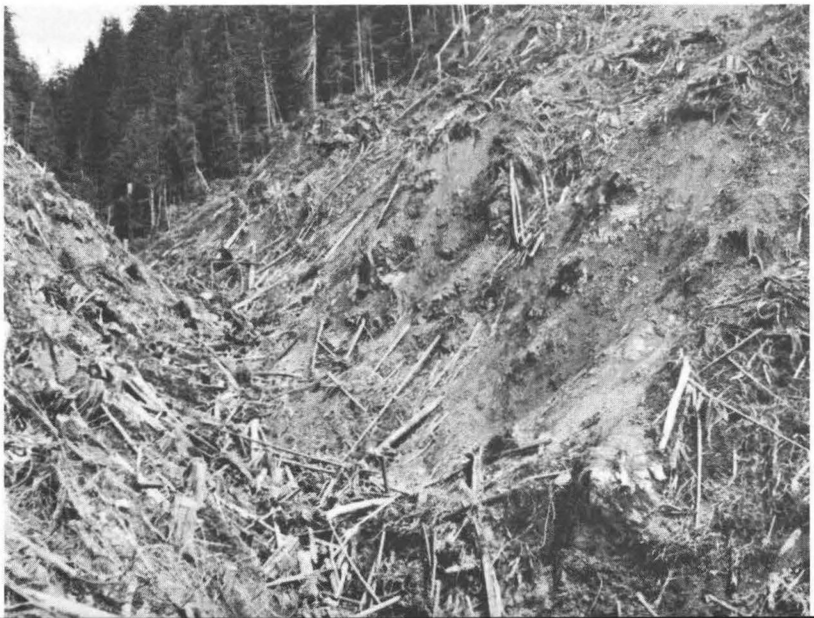


Figure 19.—Downcutting and erosion in tributary drainages maintain over-steepened slopes.

the soil is reduced by clear-cut logging, and that loss of soil organic matter as a result of logging reduces water-holding capacity. If these findings are applicable to southeast Alaska, then less weight from soil water might be expected.

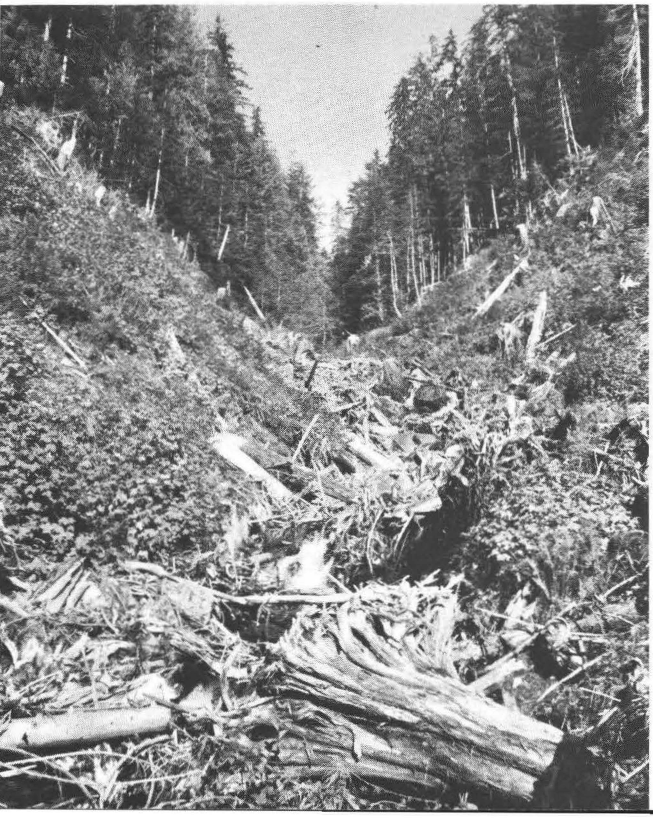
5. Weight loss by timber removal probably has no direct net effect on the likelihood of shearing. Soil mantle unloading is presumed to decrease shear strength provided by friction between soil particles. This is counterbalanced, however, by the reduced shear stress or force tending to cause shear.

6. Loss of root systems as a strength builder-maintainer in the soil mantle may be an important factor in accelerating flows after logging. This may reflect the destruction of interlaced root systems by high-lead skid-roads. It may also reflect death and gradual deterioration of root systems after clear cutting. The time lag in slide activity after logging supports this view.

7. Debris in the bottoms of steep ravines aggravates stability conditions (fig. 21). Logs and stumps on side slopes contribute to such instability by rolling or sliding into the channel. The process follows a pattern--debris accumulates in the ravine bottoms and this is followed periodically by sweeping torrent-flows.

8. Slopes of 34° (67 percent) or more are highly susceptible to failure when conventional downhill high-lead logging is used (fig. 22).

Figure 21.—Logging debris accumulated in ravine bottom.



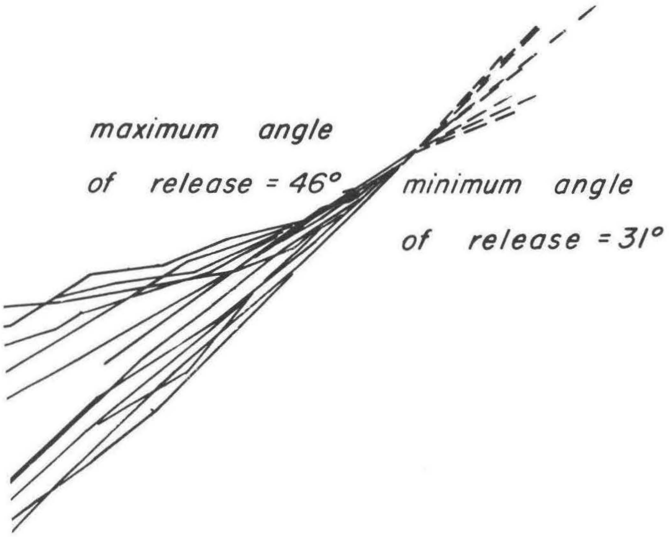

maximum angle of release = 46°
minimum angle of release = 31°

Figure 22.—Profiles of 15 landslides. The average angle of slope release is 39.5°.

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